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6. Review on Coffee Cherry Pulping Waste Water Characteristics and Treatment

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Figure 6.1: Coffee Cherry

Abstract:

Coffee is one of the important commodities belonging to the family Rubiaceae and genus Coffea. Coffee trade contributes significantly to national and international economic growth. Among the coffee producing developing countries, India is one of the good quality coffee beans producing countries.

The process of coffee beans is produced by wastewater, which is characterized by low acidic pH, higher BOD and COD. If untreated coffee effluent is being discharged, it causes harmful effects to the organisms. In this review paper, the various characteristics of coffee cherry pulping waste water, impact of coffee waste water on the environment and treatment techniques are discussed.

6.1 Introduction:

Coffee stands as one of the most widely enjoyed beverages and is a leading commodity in global trade (Figure 6.1) Its aromatic profile, coupled with the advantageous effects of caffeine and other components, entices millions of individuals to incorporate coffee into their daily routines. Originating from Ethiopia, coffee's popularity traversed regions, reaching Egypt, Yemen, Italy, and eventually spanning across all of Europe. On a global scale, coffee claims the position as the second-largest traded commodity, following petroleum. The international coffee market revolves around three primary species, each with distinctive characteristics. Arabica (*Coffea arabica*), representing 70%, boasts the highest quality in terms of taste and aroma. Robusta (*Coffea canephora*), constituting 28%, stands out for its elevated caffeine content. A smaller contributor, Coffea Liberica, holds a 2% share (von Enden et al., 2002). The essence of coffee is encapsulated in three key features: acidity, aroma, and taste. Acidity, contributing to the dry sensation experienced at the edges of the tongue and the rear palate, plays a pivotal role. A lack of sufficient acidity often results in a flat coffee. Aromatically, individuals immerse themselves by inhaling the rising vapor from the cup. The interplay between acidity, aroma, and body defines the diverse taste profiles of coffee, ranging from caramel and chocolaty to fragrant, fruity, ripe, sweet, almondy, and delicate (von Enden et al., 2002).

Coffee processing involves two main methods: dry (natural) processing and wet (fermented and washed) processing. Typically, wet processing is associated with the production of a higher-quality coffee product. Nevertheless, certain regions express a preference for dry processed coffee due to its ability to impart a fuller flavor. The geographic distribution of these processing methods is as follows: Wet processing is predominant in countries such as Bolivia, Burundi, Cameroon, Colombia, Costa Rica, Cuba, Dominican Republic, East Timor, Ecuador, El Salvador, Equatorial Guinea, Ethiopia, Guatemala, Honduras, India, Indonesia, Jamaica, Kenya, Malawi, Mexico, Nicaragua, Papua New Guinea, Rwanda, Tanzania, Uganda, Venezuela, Vietnam, Zambia, and Zimbabwe. On the other hand, dry processing is prevalent in areas like Angola, Benin, Brazil, Central African Republic, Congo, Democratic Republic of the Congo, Cote d'Ivoire, Gabon, Ghana, Guinea, Haiti, Madagascar, Nigeria, Paraguay, the Philippines, Sri Lanka, Thailand, and Togo (Chanakya & De Alwis, 2004). This distinction in processing methods contributes to the diverse and unique coffee flavors originating from different regions around the world.

Approximately half of the global coffee harvest undergoes wet processing, a method involving both mechanical and biological operations to separate the coffee bean or seed from the exocarp (skin), mesocarp (mucilagenous pulp), and the endocarp (parchment) (Shuler, 2017). The pulping process, as reported by Padmapriya, Tharian, & Thirunalasundari (2013), results in the separation of the skin and the majority of the pulp using pulpers. This fraction, accounting for about 40% of the fresh fruit's weight, is currently underutilized, leading to significant pollution challenges. In the wet method, pulping entails removing the outer red skin (exocarp) and the white fleshy pulp (mesocarp) while separating the pulp from the beans. Harvesting plays a crucial role, as immature cherries are hard and green, making pulping difficult. Correct harvesting is particularly essential for the successful wet processing of coffee. In smaller-scale operations, cherries can be pulped manually using a pestle and mortar, a labor-intensive process. The drum and disc pulpers stand out as the two most common and suitable pulping methods for small-scale units.

6.2 Coffee Production:

The coffee production process initiates with the harvest of coffee cherries, and subsequent dry or wet processing yields green coffee, the standardized trading form. However, industrial coffee production generates significant by-products such as cherry husks, cherry pulps, silver skin, and spent coffee. Historically, these by-products were often discarded, but with the substantial decrease in coffee prices, there is a growing recognition of the potential benefits for both coffee farmers and the industry in marketing these by-products. Presently, there are efforts to repurpose these coffee by-products, particularly in the food sector.

To facilitate marketing within the European Union (EU), it becomes crucial to determine whether these by-products require approval as novel food items. This exploration of alternative uses for coffee by-products not only addresses environmental concerns but also offers economic opportunities in the wake of fluctuating coffee prices.

Gebremariam & Woldesenbet Belay (2014) conducted a comprehensive study characterizing wet coffee processing waste and assessing the total reducing sugar potential of coffee waste, including pulp juice and mucilage, in Ethiopia. The volatile solid analysis revealed a high organic component in the waste, with percentages of 66.5% for pulp juice and 90.2% for mucilage. The study also indicated an acidic nature of the waste, with pH values of 4.75 for pulp juice and 3.67 for mucilage. The environmental impact of the waste was highlighted by elevated BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) values, with pulp juice recording BOD and COD values of 25,600 mg/L and 45,000 mg/L, respectively, and mucilage showing BOD and COD values of 19,810 mg/L and 33,600 mg/L, respectively. The COD:BOD ratio, indicating biodegradability, was less than 5:1. Overall, the study underscored the potential environmental challenges posed by these wastes, attributing them to their high organic content and acidic properties, leading to water pollution. To address this issue, the waste underwent hydrolysis using dilute H_2SO_4 (1%, 2%, 3%, and 4%) and distilled water. The analysis of the total sugar content revealed that the highest yield (85%) was achieved with 3% H_2SO_4 hydrolysis, while hydrolysis with 4%, 2%, 1% H_2SO_4, and distilled water resulted in values of 72.86%, 76.50%, 63.75%, and 56.66%, respectively. This exploration not only highlights the environmental concerns associated with coffee processing waste but also suggests potential avenues for utilizing these by-products.

Campos et al. (2021) conducted a study addressing the coffee sector's tendency toward increased consumption and fluctuations in international coffee prices as a commodity. Recognizing the need for strategies to alleviate the impact of high production costs on coffee-producing families while ensuring product competitiveness, the study explores the potential benefits of proper "Coffee Wastewater" disposal. This approach serves as an alternative to both mitigate environmental consequences when the wastewater is discarded without treatment and generate an additional income source for coffee growers by repurposing it in the food, pharmaceutical, or cosmetic industries. While emphasizing the importance of effective coffee effluent management and understanding its composition and toxicity, the study underscores the current lack of comprehensive reports on coffee effluent. To identify practical solutions, the research delves into economic, social, and sustainable aspects, focusing on emerging trends in the utilization of coffee residues. By investigating a new sustainable by-product, the study aims to facilitate the generation of extra income for coffee growers grappling with production costs. The impact of this approach varies among coffee producers, offering unique opportunities for waste mitigation and contributing to a more sustainable coffee production chain.

In their review, Rattan et al. (2015) highlight that the wet processing of Arabica coffee (Coffea Arabica) yields a higher quality product, commanding premium prices on the global market compared to coffee processed via the dry method. Given the context of depressed world market prices, countries with lower production costs, such as Vietnam, are expected to increasingly shift their production towards high-quality and higher-priced washed Arabicas to bolster competitiveness and revenues.

However, it is noted that wet coffee processing demands a high level of processing expertise and results in substantial amounts of processing effluents, which pose potential environmental risks. The wastewater generated from coffee processing exhibits notable characteristics, including a Biological Oxygen Demand (BOD) of up to 20,000 mg/l, a Chemical Oxygen Demand (COD) of up to 50,000 mg/l, and an acidity below pH 4. To address the environmental impact, the review discusses the composition of coffee processing wastewater and presents technical solutions for wastewater treatment through insights gained from a pilot case. The exploration of wastewater treatment strategies underscores the importance of balancing the pursuit of high-quality coffee production with environmentally sustainable practices.

In their research, Gathuo et al. (1991) investigated the significant environmental impact of the coffee processing industry in Kenya, which processes over 120,000 tons of coffee annually. With more than 1200 coffee factories contributing to pollution loads equivalent to a population of over 240,000,000, the coffee industry stands out as the foremost industrial polluter in rural Kenya. The production process results in the generation of pulp, husks, and wastewater.

Husks, a by-product, can be directly utilized as fuel, while wet pulp has the potential to be composted for use as a soil conditioner. However, the wastewater produced poses a notable environmental challenge, with a high Biochemical Oxygen Demand (BOD5) sometimes exceeding 9000 mg/l. Drawing insights from practices in India and Central American countries, anaerobic lagoons are commonly employed for wastewater treatment. In Keftya, a recommendation has been made for water re-use combined with land disposal to achieve zero discharge. Despite these methods, achieving desired environmental sustainability remains a challenge. The study proposes that anaerobic digestion with biogas production presents an attractive solution, as the generated fuel could be used for drying coffee. Considering that approximately 10,000 GJ of energy is required to dry 1 ton of coffee, the potential yield of biogas from one ton of pulp is estimated at 131 m3, equivalent to 100 liters of petrol in fuel value. This suggests a promising avenue for both environmental sustainability and energy efficiency within the coffee processing industry in Kenya.

In their study, Padmapriya, Tharian, & Thirunalasundari (2015) focused on the environmental impact of coffee production, considering that 40 to 45 liters of wastewater are generated per kilogram of processed coffee.

The wastewater from coffee industries is known for its elevated concentration of organic pollutants, posing a significant threat to surrounding water bodies, human health, and aquatic life if discharged directly into surface waters. Recognizing the critical need to address this issue, the study aimed to explore the efficacy of using Moringa oleifera seeds as a means to treat coffee effluent. Collected from Bodimetu, Theni taluka, Tamilnadu, the coffee effluent's physicochemical characteristics were initially analyzed, revealing undesirable properties. Subsequent treatment with Moringa oleifera seeds brought about significant alterations in the physicochemical properties and effectively reduced the microbial load in the coffee effluent. This research underscores the potential of natural solutions, such as Moringa oleifera seeds, in mitigating the environmental impact of coffee production, offering a promising avenue for sustainable and eco-friendly coffee wastewater management. Rattan et al. (2015) delved into the significance of the coffee processing industry as a major agro-based contributor to both international and national growth. With coffee fruits undergoing either wet or dry processing, the wet method, in particular, results in substantial volumes of high-strength wastewater, necessitating systematic treatment before disposal. Various methods have been employed to address this wastewater, with researchers exploring the efficiency of batch aeration as a post-treatment for coffee processing wastewater from an up flow anaerobic hybrid reactor (UAHR) with a continuous and intermittent aeration system. Despite the attempts to enhance wastewater treatment methods, the study highlights the inherent challenges associated with wet coffee processing. This method demands a high level of processing expertise and produces significant effluents that have the potential to harm the environment. Notably, the characteristics of wastewater from coffee processing reveal a biological oxygen demand (BOD) of up to 20,000 mg/l, a chemical oxygen demand (COD) of up to 50,000 mg/l, and an acidity with a pH below 4. The research underscores the need for effective wastewater management strategies in the coffee processing industry to mitigate environmental impact and ensure sustainable growth.

In the research conducted by Figueroa Campos (2022), the focus lies on countries engaged in processing raw coffee beans, grappling with the dual challenge of low economic returns and the severe environmental impact caused by the by-products and wastewater generated during wet-coffee processing. The processing method not only shapes the composition of green coffee beans but also influences the characteristics of the by-products and wastewater produced. Through a comprehensive analysis of coffee bean samples, by-products, and wastewater collected at various production stages, the study reveals that the composition of wastewater is intricately linked to the frequency and extent of its recycling in the processing stages. Examination of coffee beans indicates that proteins may undergo changes during processing, with fermentation potentially exerting a positive influence on the solubility and accessibility of proteins. Importantly, the different stages of coffee processing impact the constituents of green coffee beans, which, during roasting, contribute to aroma compounds and define the attributes of roasted coffee beans. This insight holds significant potential for coffee producers to enhance the quality of green coffee beans and, consequently, the overall quality of the brewed coffee. The research also explores the valorization of coffee wastes by transforming them into activated carbon, presenting a cost-effective alternative capable of competing with commercial carbons. The activation protocol, utilizing spent coffee and parchment, demonstrated similar adsorption efficiency to that of commercial activated carbon, highlighting the potential for utilizing coffee parchment and spent coffee grounds as a low-cost option for producing activated carbon.

This study not only provides valuable information about the processing journey from de-pulped to green coffee beans but also underscores the potential for sustainable and economically viable solutions within the coffee industry.

6.3 Coffee Effluent:

The effluents generated during coffee processing exhibit acidity and contain elevated levels of suspended and dissolved organic solids. Their pollution load, measured in terms of Biochemical Oxygen Demand (BOD), ranges from 2.5 to 12 grams per liter.

These effluents not only contribute undesirable color but also emit foul odors when discharged into water bodies. The coloration is of particular concern due to its impact on aesthetics, being referred to as a 'visible pollutant.' The characteristic dark brown color results primarily from the presence of vegetable extracts such as tannin, humic acid, and humates originating from the decomposition of lignin.

Additionally, by-products of wet coffee processing include coffee pulp, while waste products encompass parchment husk and coffee husk. Given the environmental implications of these waste products, it becomes imperative to implement effective and environmentally friendly treatment and disposal methods in the coffee processing industry. Addressing the environmental impact of coffee effluents is essential for promoting sustainable and responsible practices within the industry.

In the research conducted by Velmourougane & Bhat (2017), the impact of coffee effluent on soil physical, chemical, and biological properties was investigated through applications at varying rates—25, 50, 75, and 100 liters/m2. Key parameters examined included electrical conductivity (EC), pH, bulk density (BD), water holding capacity (WHC), and the content of organic carbon (OC), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). Soil flora and fauna were assessed at two depths: 0-9 cm and 9-18 cm. The study found that EC was significantly higher in the samples treated with coffee effluent compared to the water treatment (control), indicating increased electrical conductivity in the soil. However, there was no significant difference in pH values between the effluent-treated samples and the control. Bulk density was notably higher in the control treatment, while water holding capacity was elevated in the effluent-treated samples.

The content of OC, N, and P did not exhibit statistically significant variations across treatments, although K content varied significantly. Mg and S availability showed no significant difference among treatments, while Ca content varied notably, with higher availability in the water-treated samples. Interestingly, soil fauna population peaked in the treatment with 25 liters/m2 of coffee effluent applied, while soil microflora population was higher in the 0-9 cm soil depth. This comprehensive study sheds light on the nuanced effects of coffee effluent on various soil properties and provides valuable insights for sustainable soil management practices in coffee-producing regions.

In the experiment conducted by Jnanesha & Vanitha (2017), the investigation focused on understanding the influence of coffee pulp effluent on the biological and chemical properties of the soil.

Among various effluent treatments, the application of raw coffee pulp effluent, coupled with soil inoculation of pleurotus, and raw coffee pulp effluent irrigation treatment exhibited significantly higher organic carbon content in the soil (0.57% and 0.56%, respectively) compared to fresh water irrigation treatment (0.46%).

The application of raw effluent irrigation also resulted in a substantial increase in soil available nitrogen, phosphorous, and potassium (314.0, 77.5, and 416.1 kg ha-1, respectively) compared to fresh water irrigation. Fungi population was found to be higher with lime-treated effluent irrigation (9.5 x 104 cfu g-1). Conversely, coffee pulp effluent irrigation combined with soil inoculation of pleurotus recorded a higher actinomycetes population (7.2 x 103 cfu g-1) compared to other treatments.

Moreover, nitrogen-fixing bacteria, phosphorus-solubilizing bacteria, and dehydrogenase activity demonstrated higher levels in the raw coffee pulp effluent treatment and were on par with lime-treated coffee pulp effluent irrigation combined with soil inoculation of pleurotus. These findings underscore the potential positive impact of certain coffee pulp effluent treatments on soil fertility and microbial populations, providing valuable insights for sustainable agricultural practices in coffee-producing regions.

In the study conducted by Fereja, Tagesse, & Benti (2020), the focus was on addressing the pressing issue of wastewater generated by coffee processing industries in Ethiopia, which often ends up being directly discharged into rivers due to a lack of monitoring facilities. This practice poses a significant risk to the entire ecological system and the well-being of the local community, necessitating urgent attention from environmental specialists. The research aimed to explore the potential of Moringa stenopetala seed powder in ameliorating the physicochemical and bacteriological load of coffee processing wastewater. Optimization of adsorbent dose and contact time for reducing turbidity and chemical oxygen demand (COD) was carried out using standard methods. Moringa stenopetala seeds, collected from Dilla University campus, were ground into a fine powder. The powder was characterized using scanning electron microscopy (SEM) and X-ray diffractometer (XRD), revealing an amorphous morphology conducive to retaining impurities. Treatment with Moringa stenopetala seed powder significantly improved the physicochemical and biological quality of the wastewater, achieving a remarkable 99.43% reduction in turbidity and a 99.16% reduction in COD at an adsorbent dose of 80 mg L−1 and contact times of 60 min and 45 min, respectively. This research establishes that Moringa stenopetala seed powder holds promising potential for enhancing the quality of wastewater. Implementing such a system could prove to be economically, environmentally, and socially feasible, offering a sustainable solution to address wastewater challenges in coffee processing industries.

Ramos-Vaquerizo et al. (2018) conducted a study focusing on the substantial volumes of wastewater generated by coffee processing, emphasizing the need for systematic treatment before disposal. The research aimed to assess the efficacy of different hydraulic retention times (HRT) in treating coffee processing wastewater (CPWW) using a laboratory-scale Expanded Granular Sludge Bed (EGSB) bioreactor, with varying HRT ranging from 3 to 9 days. The EGSB operated under mesophilic conditions (26 ±2°C) with an average pH of 7.5 ±0.2 to determine the chemical oxygen demand (COD) removal efficiency.

The results indicated that as the HRT increased from 3 to 9 days, the COD removal efficiency improved from 94% to 98%, with the α factor remaining stable at 0.98 throughout the bioreactor's operation. Notably, HRTs between 7-9 days produced effluents that met the permitted COD concentration standards set by the World Health Organization (WHO) and Official Mexican Environmental Regulations. The findings highlighted that a 9-day HRT yielded the highest COD removal, suggesting that the EGSB bioreactor presents a sustainable alternative for addressing environmental concerns related to CPWW when compared to conventional treatment methods. This research underscores the potential of optimized HRTs in EGSB bioreactors as a promising solution for the environmentally sound treatment of coffee processing wastewater.

Ijanu et al. (2020) delved into the global dynamics of coffee production, highlighting its status as the second-largest traded commodity worldwide, following petroleum. The scale of commercial coffee cultivation, driven by its significant international demand, involves production processes that utilize substantial water volumes, resulting in the discharge of contaminated water. This wastewater is often laden with toxic chemicals such as tannins, phenolic compounds, and alkaloids, hindering biological degradation. Microbial processes engaged in breaking down these organic substances in water bodies lead to a gradual oxygen depletion, as measured by Chemical Oxygen Demand (COD). As the demand for oxygen surpasses the available supply, the wastewater environment shifts towards anaerobic conditions. The review conducted a comprehensive examination of current methods employed in coffee wastewater management, encompassing both physicochemical and biological approaches. It delineated the advantages and disadvantages of these methods, including high costs, operational complexity, and extended time requirements. Proposing an alternative, the review highlights the ion exchange technique as a more favorable option, given its dual functionality as both an ion exchanger and absorber. This suggestion is grounded in the potential for enhanced efficiency and efficacy in managing coffee wastewater, offering a promising avenue for addressing the environmental challenges associated with coffee production processes.

6.4 Coffee Effluent Treatment:

The wastewater emanating from coffee processing units contains various organic impurities, including pectin, proteins, and sugars Campos et al. (2021). The measurement of Chemical Oxygen Demand (COD) serves as an essential parameter, quantifying the amount of dissolved oxidizable organic matter, encompassing non-biodegradable components within the wastewater (Kalshetty et al., 2014). Analogous to Biological Oxygen Demand (BOD), which denotes the oxygen required for the decomposition of organic compounds within wastewater at a permissible level of 20 g L^{-1}, COD provides a comprehensive assessment of water quality (Kitane et al., 2020). The test conducted according to the EPA method enables the measurement of virtually all organic compounds, allowing for the removal of 80% of the pollution load within the acceptable limit of 50 g L^{-1} (Shan et al., 2017).

Water turbidity, a phenomenon caused by suspended particles with varying diameters, contributes to scattering and absorption of electromagnetic radiation in the infrared (IR) and visible (VIS) regions. These particles, found in both mineral and organic forms in surface waters, are particularly prevalent in wastewater treatment plant effluents, with organic suspended matter being a common observation (Bayo, Olmos & López-Castellanos, 2020).

Understanding and monitoring parameters such as COD and turbidity play a crucial role in assessing and managing the quality of water impacted by coffee processing activities.

In recent years, natural coagulants have gained increasing popularity, presenting a viable alternative to chemical coagulants with numerous associated benefits. Traditional chemical-based coagulants like alum and ferric salts, while effective in water and wastewater treatment, come with significant drawbacks, including the generation of harmful and voluminous sludge. This has prompted the exploration of natural coagulants derived from plant-based materials, marking a shift towards safer and more eco-friendly alternatives.

Natural coagulants can be extracted from various sources such as plants, microorganisms, and animals. Plants, in particular, serve as a rich source of natural coagulants (NC) that can be employed in the coagulation-flocculation processes of water and wastewater treatment. Examples of plant-based natural coagulants include Calpurnia, Neem, Tulsi, Moringa, Orange Peel, Sponge Guard, Vetiver, Banana Peel, among others, all of which exhibit effectiveness in water and wastewater treatment. The mechanism of action for plant-based natural coagulants involves either polymer bridging or charge neutralization, offering a sustainable and environmentally friendly solution to the challenges posed by chemical coagulants. The adoption of natural coagulants represents a positive step towards more sustainable and ecologically conscious water treatment practices.

In a study by Maurya & Daverey (2018), the efficacy of four plant-based natural coagulants, namely banana peel powder, banana stem juice, papaya seed powder, and neem leaf powder, was assessed for turbidity removal. The FTIR analysis of banana peels indicated the presence of functional groups such as carboxylic acid, hydroxyl, and aliphatic amines, suggesting their potential role in coagulation-flocculation by neutralizing the charge on impurities in water. This insight into the chemical composition enhances our understanding of the mechanisms underlying the coagulation process. In a related study, Sulaiman et al. (2017) explored the coagulant properties of Moringa oleifera seeds extract. The research quantitatively evaluated the extract's effectiveness in wastewater treatment and investigated its coagulation mechanism. Moringa oleifera seeds are known for their richness in bio-active components and are utilized as a natural coagulant for water treatment. This study contributes valuable insights into harnessing the coagulation potential of plant-based resources for sustainable and effective wastewater treatment processes.

In a study conducted by Ntalani et al. (2021), the amino acid composition of seeds from Citrullus lanatus, Vigna unguiculata, and Zea mays, along with the proteins present in the coagulating solutions derived from the seed powders of these plants, was thoroughly characterized. Glutamic acid emerged as the most abundant amino acid in the seeds of all three plant species, exhibiting a negatively charged side chain at neutral pH. Notably, the seed powders from these plants demonstrated robust coagulant activity, with turbidity reduction percentages exceeding 80%. This research sheds light on the amino acid profiles and coagulation potential of these plant seeds, providing valuable insights for potential applications in water treatment processes. In a related study by Zhang et al. (2015), proteins within extracellular polymeric substances extracted from anaerobic, anoxic, and aerobic sludges of a wastewater treatment plant (WWTP) were investigated to elucidate their origins and functions. Employing shotgun proteomics, the study identified and classified 130, 108, and 114 proteins in anaerobic, anoxic, and aerobic samples, respectively.

Predominantly originating from cells and cell parts, these proteins exhibited major molecular functions related to catalytic and binding activities. The research highlighted the diverse roles of extracellular proteins in activated sludges, including binding to multivalent cations and organic molecules, as well as catalysis and degradation. Catalytic activity proteins were more prevalent in anaerobic sludge compared to anoxic and aerobic counterparts, suggesting a link between the macro characteristics of activated sludges and the micro functions of extracellular proteins in the biological wastewater treatment process. These findings contribute to a comprehensive understanding of the intricate interactions within wastewater treatment systems.

In a study conducted by Silva et al. (2012), the role of extracellular polymeric substances (EPS) in biomass aggregation and settleability within wastewater treatment systems, particularly membrane bioreactors (MBR), was investigated. EPS play a crucial role in membrane fouling in MBRs. Proteins were identified as the predominant component of EPS produced by activated sludge, demonstrating correlations with sludge properties such as settling characteristics, hydrophobicity, and cell aggregation. Previous EPS proteomic studies faced challenges, including interference from other EPS molecules during protein analysis. The study introduced a successful strategy for identifying proteins in soluble and bound EPS extracted from activated sludge in a lab-scale MBR. Various pre-concentration methods, including lyophilization, centrifugal ultrafiltration, and concentration with a dialysis membrane coated by a highly absorbent powder, were employed. The highly absorbent powder method without prior dialysis achieved the highest protein concentration factors. Four protein precipitation methods—acetone, trichloroacetic acid (TCA), perchloric acid, and a commercial kit—were then tested, with protein profiles compared using sodium dodecyl sulphate polyacrylamide gel electrophoresis. Both acetone and TCA were deemed necessary for optimal coverage of soluble EPS proteins, while TCA emerged as the superior method for bound EPS proteins. Mass spectrometry analysis of selected profiles revealed the identification of a significant number of proteins, ranging from 25 to 32 for soluble EPS and 17 for bound EPS. These findings contribute to a better understanding of EPS composition and provide valuable insights into strategies for mitigating membrane fouling in wastewater treatment systems. In a comprehensive study conducted by Koul et al. (2022), the current state of water treatment (WT) and the pressing need for upgrading conventional WT technologies due to water resource depletion and environmental pollution concerns were explored. Focusing on natural coagulants, the study aimed to compile and analyze existing literature on their application in surface water purification. Through a systematic review of 237 articles sourced from PubMed, Scopus, Web of Science, Google Scholar, CAB Abstracts, and various websites, the research provides detailed insights into the merits and limitations of natural coagulants, strategies to enhance their coagulation performance, and their coagulation mechanisms, efficacy, valorization potential, and sustainability.

The findings suggest that while chemical coagulants are efficient in WT, their high cost, toxicity, and associated health issues render them non-sustainable. Natural coagulants emerge as a promising alternative due to their ready availability, cost-effectiveness, ease of use, biodegradability, non-toxicity, eco-friendliness, effectiveness, and the generation of lower sludge volumes. Operating through an adsorption process involving polymeric bridging or charge neutralization, natural coagulants exhibit WT efficiency comparable to chemical counterparts, ranging from 50 to 500 nephelometric turbidity units (NTUs). This positions them as viable options for WT applications, particularly in rural areas of developing countries, contributing to health security. Despite their known benefits, the study notes the limited acceptance, commercialization, and global industrial application of natural coagulants. The authors emphasize the necessity for more in-depth investigations into their mode of action, widespread adoption, and commercialization as a sustainable alternative to chemicals, fostering a circular economy in water treatment.

6.5 Conclusion:

Hence, sustainable wastewater treatment is needed of hour and it should be an environmentally friendly method like natural coagulant treatment. The treatment should not cause any secondary pollution like conventional treatment. Even though, more studies are needed to bring an efficient product from natural materials for wastewater treatment.

6.6 Acknowledgement:

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